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HOWDEN MOSS: A STUDY OF VEGETATIONAL HISTORY IN UPPER TEESDALE

BY

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A dissertation submitted as part requirement for the degree of M.Sc. in Ecology (by Advanced Course) 1975 to 1976.

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ABSTRACT

The peat deposits at Howden Moss, Upper Teesdale, have been examined stratigraphically and pollen analytically. The present state of the bog is described and pollen diagrams are presented for three sites. The results show that peat formation had begun by the early post-glacial period, zone V, and growth apparently continued up to the present time. The area was colonised by birch trees early in its development. Open birchwood persisted on the site during the expansion of mixed oak forest into the valley bottom. This dichotomous situation continued until the birch wood on the fell was replaced by blanket bog communities. The late-glacial relict flora which is associated with some sites in Upper Teesdale is not found at Howden Moss. The pollen record provides no evidence for its past existence in the area.

INTRODUCTION

At the present day, large areas of the Pennines are covered by blanket bog, bearing a surface vegetation of heather and cotton-grass. The major part of this is treeless and sparsely inhabited. Much of the surface shows evidence of erosion. In places this has progressed to the stage where bare rock is exposed, notably on the highest parts of the fells.

Intact peat deposits provide a unique stratigraphic record of climatic and vegetational changes. Identification of plant macrofossils in the peat provides evidence of the vegetation which existed at that site in the past. Comparison of these plant communities with similar extant vegetation suggests the prevailing climate during the period in which a particular type of deposit was laid down.

Working on peat deposits in Scandinavia during the late 1800's, Blytt and Sernander reasoned that the different layers observed were due to vegetational change in response to climatic variation. On this basis they divided Post-glacial time into a number of periods of differing climatic conditions. However, these are not entirely applicable to Britain.

Blytt x Sernander Periods	Climate	
Sub-Atlantic	Cold ± Wet	(present)
Sub-Boreal	Warm ± Dry	
Atlantic	Warm ± Wet	
Boreal	Warm ± Dry	
Pre-Boreal	Sub-Arctic	

Following this work, the introduction of pollen analysis of organic deposits by Von Post allowed the further reconstruction of vegetational history. In the Pennines work carried out by Erdtmann (1928) showed that the peat deposits were Post-glacial in origin and could be related to the climatic sequence formulated for Scandinavia.

Godwin (1956) produced a zonation scheme in which he correlated the climate with its associated vegetation on a time scale. This sequence is applicable, with some modifications, especially in the chronology, throughout England and Wales. (Fig. 1).

Dating		Vegetation	Climate	Forest	Cultures
Years	Pollen zone	England + Wales	Blytt + Sernander	Cover	
2000 A.D. B.C. 500	VIII	Alder Birch Oak Elm Beech	Sub- Atlantic Rapid Deterior- ation		Norman Anglo- Saxon Romano- British Iron Age
3000	VIIb	Alder Oak Elm Lime	Sub- Boreal		Bronze Age Neolithic
5500	VIIa	Alder Mixed Oak Forest	Atlantic		Mesolithic
	a VIb c	Pine Hazel	Boreal		
7700	V	Hazel- Birch - Pine			
8300	IV	Birch	Pre-Boreal		

Invesigations carried out in the Pennines using pollen analysis have shown that most of the peat deposits date from the beginning of the Atlantic period. Conway (1954) concludes that blanket bog formation began about the time of the Boreal-Atlantic transition in the southern Pennines.

In the northern Pennines scattered peat deposits date from the Boreal period (Godwin and Clapham, 1951; Johnson and Dunham, 1963; Hewetson, 1969; Squires, 1970), and peat formation at some sites dates from Late-glacial time (Turner etal., 1973). However, the majority of the blanket bog developed after these periods.

At many sites the so-called 'blanket peat', composed of the remains of Calluna Vulgaris, Eriophorum angotifolium and vaginatum and various Sphagna, overlies a peat deposit rich in wood. The evidence implies that, at an earlier period in the Post-glacial history of the Pennines, much of the countryside bore an extensive cover of woodland.

Analysis of the wood has shown that most of these trees were birch and pine (Raistrick and Blackburn, 1932; Johnson and Dunham, 1963). However, the use of pollen analytical techniques has shown a period in which oak, elm, alder and lime were present, at least in some valleys. (Pearsall, 1950; Squires 1970; Turner etal, 1973).

Collating the many recorded observations provides a picture of the region initially colonised by birch, pine and hazel. Subsequently there was an invasion of mixed oak forest species which spread from the surrounding lowlands into the Pennine valleys. Dense forest gradually expanded replacing the pre-existing trees, although most of the upper hillsides and fell tops were still colonised by birth woods. Where conditions were suitable, alderwoods existed.

This situation persisted until a combination of climatic, edaphic and anthropogenic factors resulted in the destruction of both hill and valley woods. On the fellsides the formation of blanket peat was initiated as the tree cover was replaced by heath and bog communites. In the valley bottoms, forest clearance began to systematically destroy the woodland until today only a few patches of trees remain.

In the northern Pennines a number of studies of vegetational history have been made in Upper Teesdale. The arctic-alpine plants found there have attracted a great deal of attention (Blackburn, 1931; Godwin, 1949; Piggott, 1956), and the area is considered to be of great botanical importance. Many of the plants, such as Gentiana verna and Kobresia simpliciuscula, are rare in Britain.

Work was carried out at a number of sites in Upper Teesdale between 1966 and 1970 in order to determine the vegetational development of the area with a view to further understanding the survival of the rare species. The results have been published by Squires (1971) and Turner et al (1973).

The present study was undertaken for several reasons. Howden Moss lies outside the area where the Teesdale rarities are now found but it is very close to that part of Upper Teesdale. If those plants had been more widespread in the past, then the area around Howden Moss would be a likely habitat for them. The pollen record provided by the peat of the bog could then provide a further contribution to the history of the rarities.

Alternatively, should no record of the plants be found, then perhaps the pollen diagrams could help to explain why the rare plants did not exist there while being present elsewhere in Upper Teesdale.

HOWDEN MOSS

1) Topography

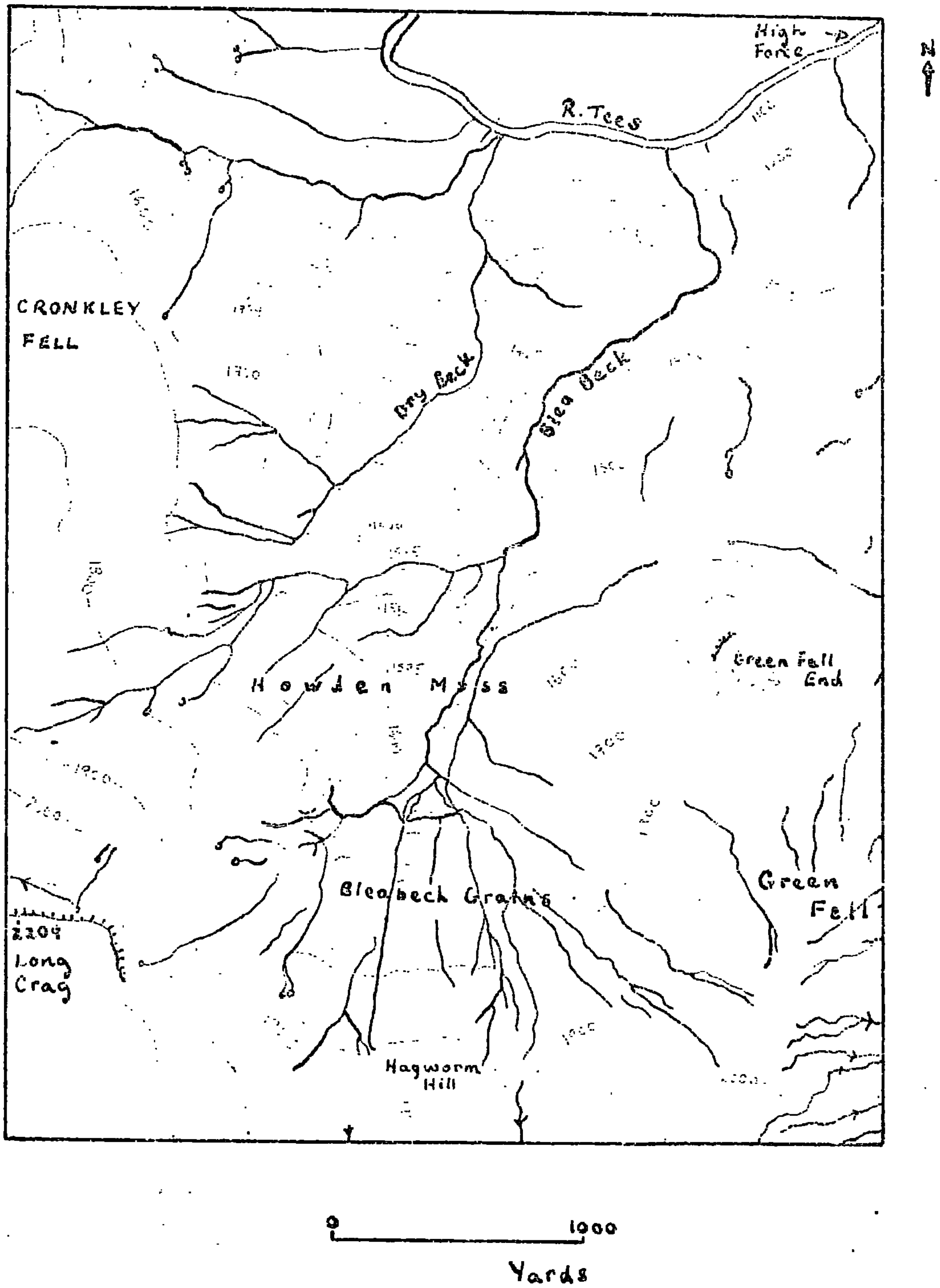
Howden Moss is an area of peat bog lying on the south side of Teesdale, some five miles due west of Middleton and in a south-east direction from Widdybank and Cronkley Scar. (at grid reference NY865260).

In area the bog measures approximately one mile by half a mile, and reaches a maximum height of 1600 feet O.D. It occupies what is effectively a valley position running north-eastwards between the lower slopes of Long Crag and Cronkley Fell to the west, and of Green Fell on the east. To the north the land falls away towards the River Tees, while to the south west the ground rises towards Long Crag. (fig. 2).

The moss is more or less isolated from the surrounding fells by a drainage system formed by the streams, Blea Beck, Crake Sike and Dry Beck. An extensive network of channels runs down from the fells to join these watercourses.

On approaching Howden Moss the impression is of a raised bog, rather than an extent of blanket peat, the bog probably having formed initially in a depression in the valley floor.

Fig.2 Map of Teesdale showing the location of Howden Moss



2) Geology

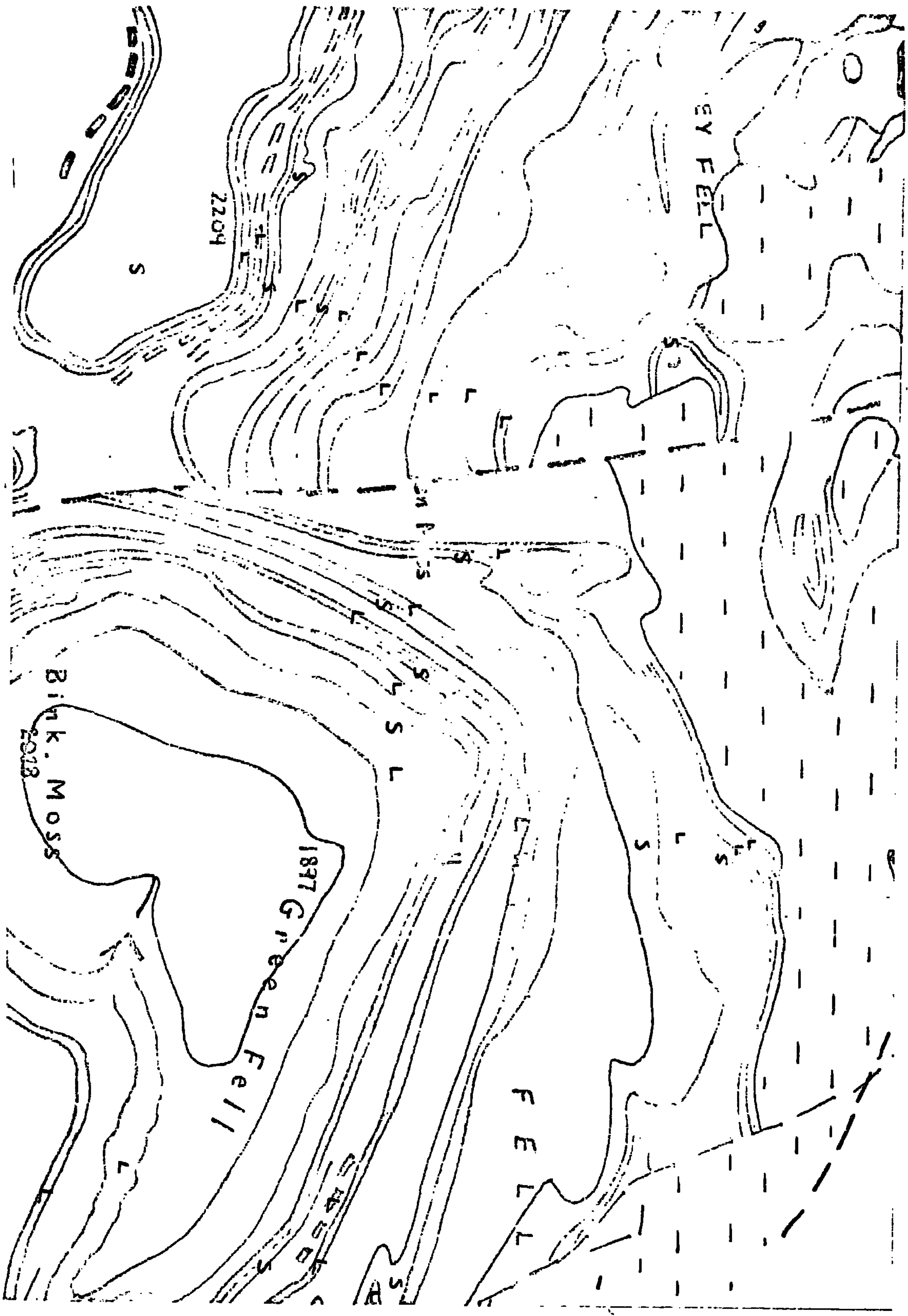
Much of the land of Upper Teesdale is covered by glacial drift and peat. The greater part of this is underlain by rocks of carboniferous age consisting of layers of limestones, sandstones and shales. Into this series are intruded outcrops of quartz-dolerite from the Great Whin Sill. These are evident at High Force and Holwick Scar. This igneous intrusion was responsible for the metamorphosis of the rocks which produced the 'sugar limestones' upon which the Teesdale relict flora depends for its existence. (Johnson et al, 1971).

The rocks underlying Howden Moss are those of the middle limestone group, a sequence of predominantly dark coloured limestone bands with intervening shales and sandstones. Above the moss, at Green Fell End, this is continued into the upper limestone group, (fig. 3). Howden Moss itself is split geologically by the Burtreeford Disturbance, a north-south trending fault which has an eastward downthrow of some 600 feet.

The Moss and most of the surrounding fells are covered now by peat but in places on the upper fells at Long Crag and Green Fell End, and also in the stream beds, the limestone and sandstone is exposed. However. although this resembles the geology of those sites which now bear the Teesdale rarities, it has been shown that the relict flora is associated particularly with outcrops of the Melmerby Scar and Robinson limestones of the lower limestone group and not with the overlying darker pigmented rocks.

At Howden Moss, the underlying rocks can have had little direct influence upon the post-glacial vegetation which developed above them. The rocks are effectively insulated by a covering of boulder clay which has been laid down over at least the major part of the area.

FIG 3. GEOLOGY



→ Z

L = LIMESTONE

S = SANDSTONE

¦ ¦ = QUARTZ-DOLERITE

In the southern end of the bog this is evident as a stiff blue clay beneath the peat. Along the streams can be seen exposures of light gray clay forming the stream beds and underlying the adjacent peat.

According to Dwerryhouse (1902) the glacial drift extends up to the 1750 ft contour. This is apparently the result of the last glaciation. The glacier ice former in the upper part of Teesdale, in the semi-circle of hills at the head of the dale, and then flowed down the valley. However, a large part of Green Fell End remained free from the ice.

Dwerryhouse maintains that an ice damned lake occupied the upland valley of Howden Moss and Blea Beck Grains. The overflow of this Blea Beck Lake was over the col at Hagworm Hill above the moss. (figure 2).

In the lower norther half of Howden Moss there is a ridge of material running west-east which appears to impede the streams draining the area. This causes Crake Sike to run eastwards along the uphill side of the ridge to join Blea Beck which then cuts a path through on the east side between the ridge and Green Fell End. The material thus exposed resembles morainic deposits.

The glacial drift is generally strongly calcareous having been derived in part from limestone. This would provide mineral-rich ground water to overlying vegetation.

3) Surface Vegetation

The surface of the bog can be divided into three sections, based on a combination of topography and surface vegetation. The divisions are shown on figure 4.

The northern section of the moss is isolated from the main body of the bog by the stream known as Crake Sike. This is a deeply incised channel running from west to east to meet the Blea Beck. It's bed is generally of boulder clay, but in places there are outcrops of limestone.

This part of the bog has a relatively dry surface on which the dominant vegetation is *Calluna vulgaris*, with some *Empetrum nigrum* and *Sphagnum papillosum*. A number of shallow man made drains cut the surface of the peat and in the southern half of this section there are a number of burnt patches. In the latter are the remains of burnt Calluna stems protruding through a surface mat of *Sphagnum papillosum*, *S. rubellum* and *Erica tetralix*.

The main part of the bog lies south of this eastward channel of Crake Sike and is delimited by Blea Beck and the northward flowing tributaries of Crake Sike. The northern section of the area resembles that previously described, both in vegetation and management, but in general is rather wetter. There is a more generous surface covering of *Sphagnum*, several patches of *Rubus chamaemorus* and occasional specimens of *Lycopdium selago*.

The wettest part of the bog is to the south of this section and is dominated by *Eriophorum vaginatum* with *Erica tetralix* and *Sphagnum* also prominent. (*S. papillosum* and *S. rubellum*). Artificial drainage has been attempted only on the northern edges of this area and it is untouched by burning.

In general therefore, the plant communities consist of few species. However, in the area of Blea Beck Loup and the part of Crake Sike adjacent to Blea Beck there is a completely different vegetation. On the flatter areas of these parts the peat is thin or absent and a soil has developed which bears a grassland vegetation. Apart from various grasses, species identified were: _Galium palustre_, _Cirsium vulgare_, _Thymus drucei_, _Potentilla erecta_, _Bellis perennis_, _Trifolium pratense_. _Ranunculus acris_, _Equisetum arvense_ and _Polypodium vulgare_. Grasses are also present along the steep banks of Blea Beck to the south but the other plants are absent. Similarly this is true of parts of the Crake Sike tributaries, which in a few places where drainage is impeded contain patches of the rush _Juncus Effusus_.

Lime rich water drains from Long Crag producing a flush vegetation about the points at which the tributaries of Crake Sike arise.

4) Erosion

The two major water courses, namely Dry Beck and Blea Beck, together with that part of Crake Sike leading into Blea Beck, appear to be long-standing. The latter two are particularly deeply incised. It may be supposed that they have existed since early post-glacial times.

However, not all the channels have been formed for so long a period. Peat erosion and stream formation is visibly in progress at Howden Moss at the present time. One process, similar to one described by Johnson and Dunham (1963) in Moor House blanket peat, is particularly obvious.

It is initiated by water percolating through the body of the peat and draining over the underlying substrate. The consequent internal erosion produces a channel in the peat. Once a sufficient amount of material has been carried away the roof of the stream collapses showing a deep channel through the peat. Continuation of this process may lead to large scale erosion.

At Howden Moss a number of channels are evident in various stages of development. Some are visible as discontinuous channels, others are disclosed only where they flow into other streams. A large number of these embryonic channels do not cut through to the base of the deposit but flow instead along the surface of the lower wood peat, often exposing tree branches which lie horizontally beneath the water.

A few of the channels have reached maturity. In these the water now runs over a bed of clay, but the erosion continues as the streams cut into the banks of peat on either side. In places this process resembles the formation of a river meander. On one side of the stream is a steep bank, often with a large fallen block of peat at its base. The opposite bank by contrast is gently graded, the eroded peat being redeposited and covered with a litter of birch wood. This is most evidently progressing at the Crake Sike tributary beside the pollen site HMC (see p.36)

The most severe erosion has occurred where several streams feed into Dry Beck adjacent to the site HHK. Here a large amount of peat and the underlying deposit of boulder clay has been stripped away, leaving an assortment of rubble lying in the watercourses. This is composed largely of rounded blocks of black limestone of varied size, but some sandstone and granite is also present.

In general the surface of the bog has a continuous vegetation cover and there is apparently little erosion other than that resulting from channel formation. The peat here has insufficient depth and wetness to suffer from the bog bursts evident in deeper blanket peat.

Human influence is the only other factor of importance and the effects of this appear very limited. The main causes of peat erosion which are attributable to man are over-grazing by sheep, digging of drainage ditches and periodic burnings. All of these may initiate erosion by destroying the vegetation cover, so exposing the surface peat to the influence of wind and rain.

Howden Moss is maintained as grouse moor. The management policies employed result, to a large extent, in the exclusion of sheep from the bog, preventing the possibility of over-grazing.

Regular attempts are made to dry the surface by means of ditches cut mechanically into the peat. Although these are much in evidence when traversing the bog, they seem at present to be producing little effect, either as drainage channels or as initiators of erosion. The tendency is for the channels to partly fill with water and either remain this way or become infilled with Sphagnum cuspidatum in the wetter areas of cotton-grass. The main damage is the disturbance of the surface peat stratigraphy in that ridges and furrows are produced.

Periodic burning is carried out to provide new heather growth, and a number of burns are visible. The bare ground produced is colonised by Sphagnum and Eriea tetralix, although occasionally a few bare hummocks of peat are evident. Surface runoff is therefore limited and no erosion channels produced in this way can be seen. Some peat loss probably occurs during burning followed by removal of the dried out upper peat, but the amount lost appears to be small.

5) Stratigraphy

The general procedure for investigation peat stratigraphy is to take line transects across the bog and examine the peat at predetermined points. However, after a preliminary examination of Howden Moss it was decided that this method could not be applied in this case. The decision was taken primarily because of the large size of the area involved. It was felt that the results obtained would not justify the amount of time and effort which would have been involved.

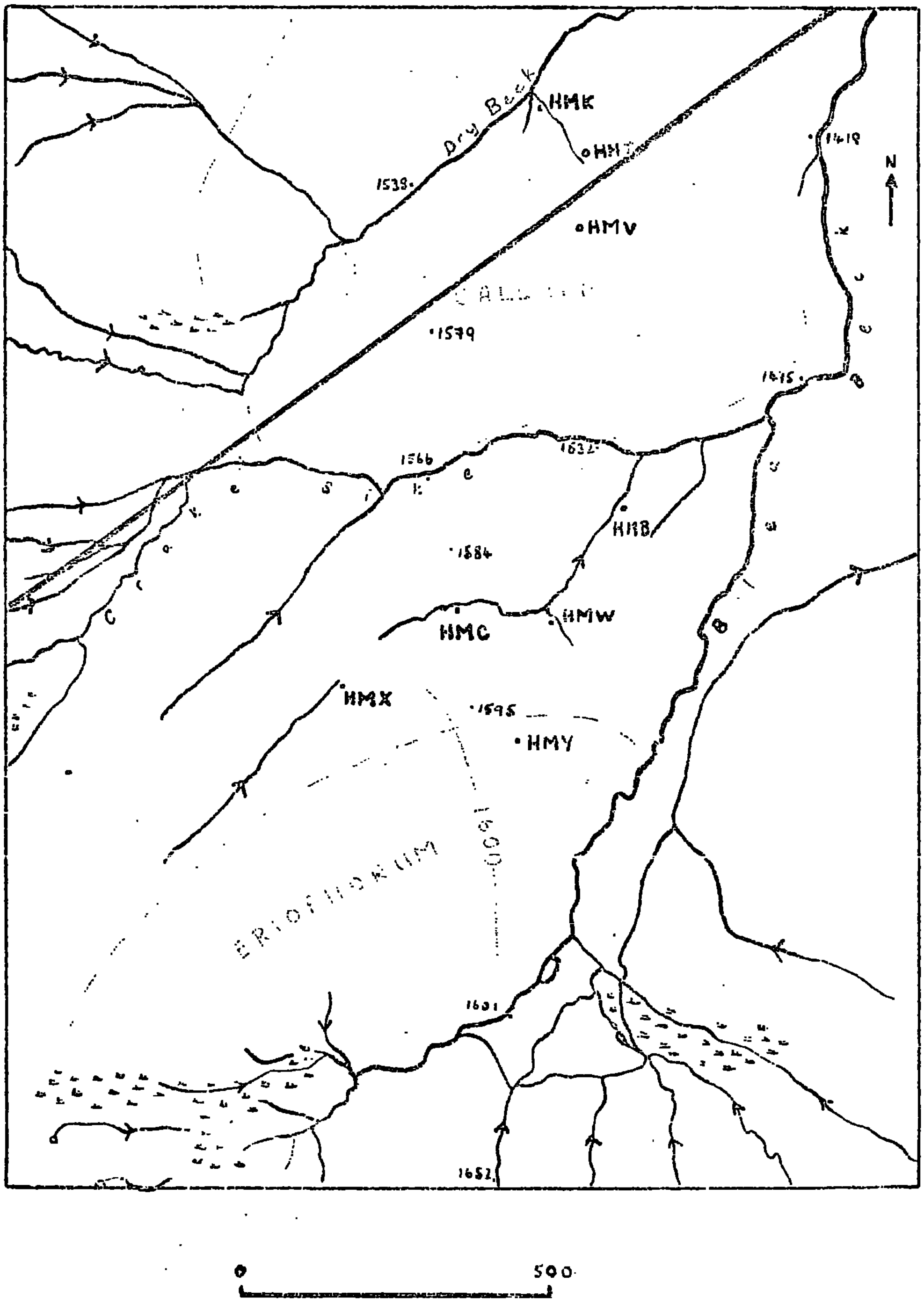
The stratigraphy of the bog was, therefore, initially examined at a number of exposures along the sides of streams. Subsequently a number of borings were made, with a Russian-type peat sampler, to supplement these. The locations of representative sites are shown in Figure 4, and the peat stratigraphy is displayed diagrammatically in Figures 5 and 6.

In most of the sections examined there is a clear division of the peat into two distinct layers. The lower layer, which overlies an inorganic clay in all but two instances where it occurs, is light brown or yellow brown in colour, well humified and contains numerous wood remains in the form of twigs and bark. Sometimes remains of Phragmites leaves and rhizomes are intermingled with the wood, so that the deposit can be described best as a wood or fen peat.

Towards the top of this layer occur many branches, trunks and boles of trees, most of the latter apparently still in their original positions of growth. These were identified microscopically in the laboratory as being remains of birch trees. The quantity of wood found indicates that the moss was covered, to a large extent, by an open birch wood during at least the latter part of the period in which this peat was accumulating.

Above this wood layer there is a sharp transition to a darker, generally damper peat, containing identifiable remains of Calluna, Eriophorum and Sphagnum species. Frequently layers of Calluna twigs are associated with the lower part of this peat together with layers of

Fig. 4 Locations of Pollen Sites.



Southern Limit of U. Teesdale N.N.R.

HMB, HMC, HMK : Pollen Sites

HMJ, HMV, HMW, HMX, HMY = Stratigraphic Sites

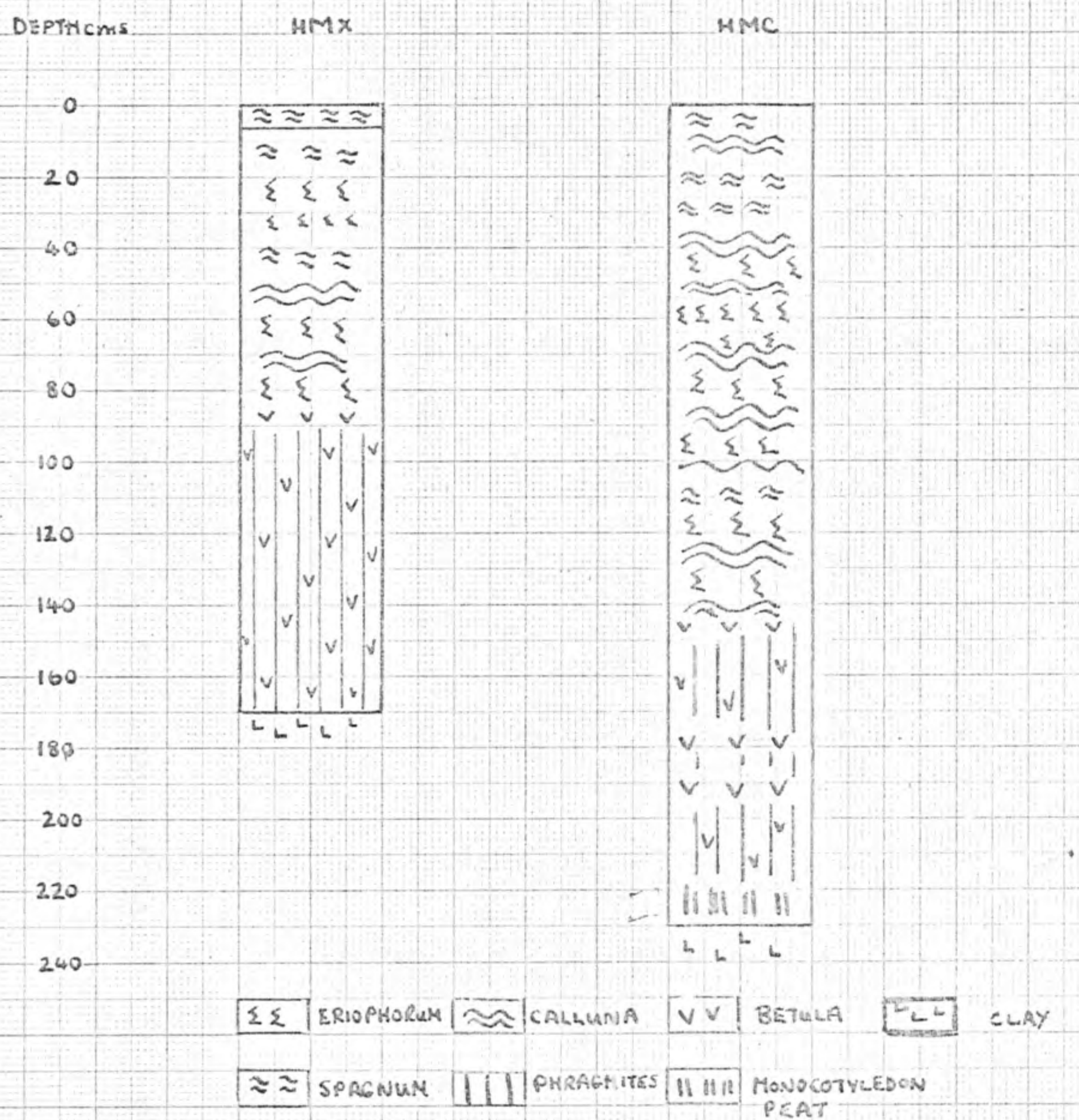
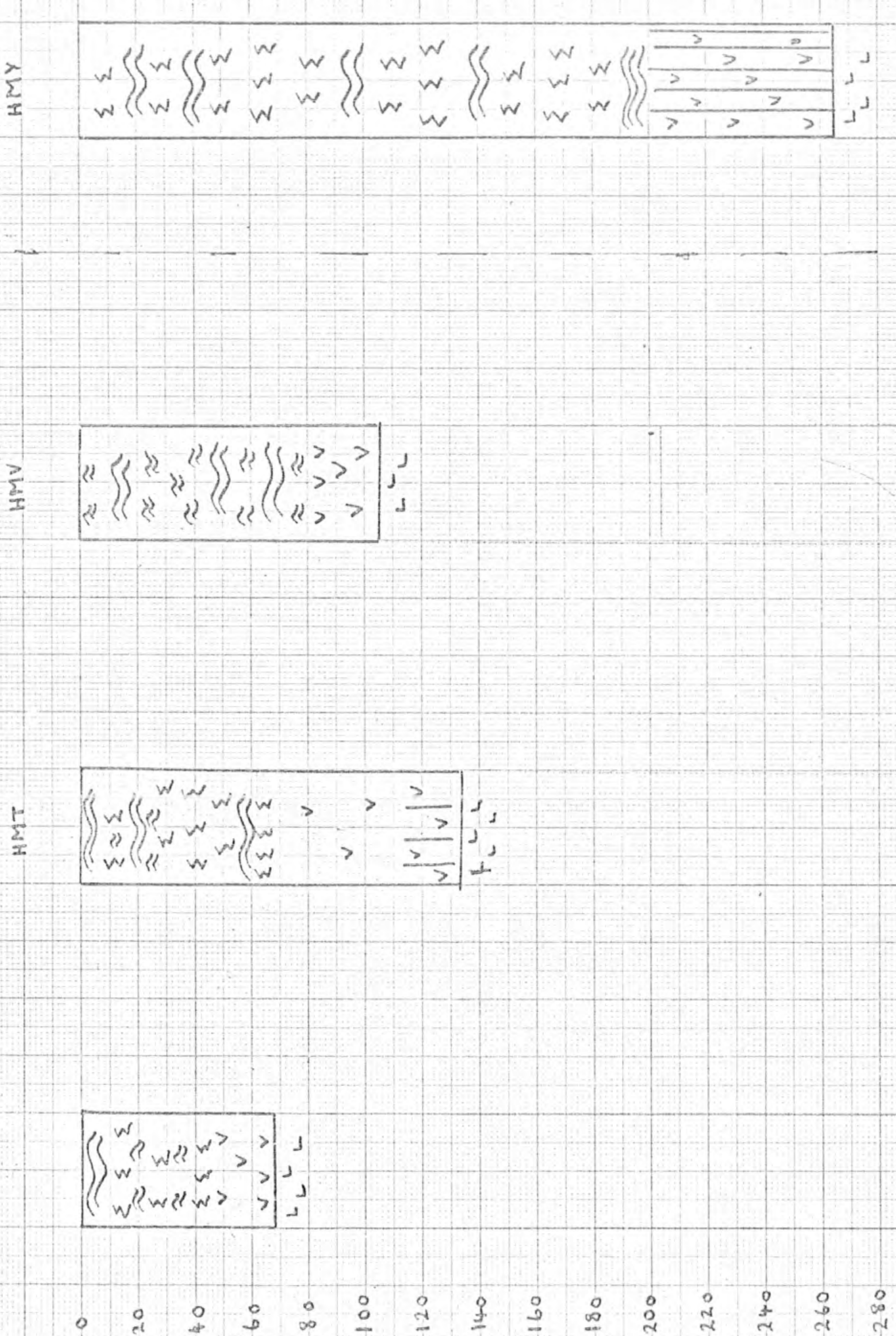


FIG. 5 PEAT STRATIGRAPHY

FIG. 6 PEAT STRATIGRAPHY



Eriophorum tussocks. These grade into a more or less amorphous peat formed from *Calluna*, *Eriophorum* and *Sphagna*. Towards the surface of the deposit the peat tends to become more fibrous and *Eriophorum* dominated. At some sites there are layers of *Sphagnum* present, either between or instead of the upper *Eriophorum*, followed in general by a surface litter of *Calluna* remains or by a hummock of *Sphagnum*.

The transition between the two types of peat, (wood and 'blanket' peats), is so distinct that it seems to represent a rather rapid change in surface conditions on the bog. The stratigraphic change suggests an alteration in the mineral supply to the vegetation. This could be due to a developmental process or to a climatic change. These two factors will be discussed at a later stage.

(see p. 41)

POLLEN ANALYSIS

During the stratigraphic examination of the bog, it was decided to take peat samples for palynological examination in the laboratory. The sites chosen were HMB, HMC and HMK, and the locations of these can be seen on Fig. 4. These were all stream-side sites where peat sections had been exposed by erosion.

Prior to taking samples, a fresh peat face was exposed at each site using a spade. The peat wall was then cleaned with horizontal strokes of a clean blade in order to remove any material which had been carried from one peat layer to another during the initial cutting. The stratigraphy of the site was then examined and noted. Peat samples were taken from representative levels, generally at 10 cm. intervals, working from the top of the deposit downwards. The sampling was carried out by pressing glass tubes into the deposit so that some was forced into the tube, careful extraction of the tube thus resulted in the removal of the peat sample from the section. The site and level from which the sample came was noted on each tube, eg. HMB 10 cm.

In the laboratory the peat samples were treated with 10% NaOH to break down the deposit and sieved to remove large plant remains. The samples were then acetolysed to further reduce the amount of organic material. The pollen grains, which are more or less isolated and concentrated by this technique, were mixed with glycerine jelly containing the dye safranin and mounted on slides ready for counting. (Detailed accounts of pollen preparation can be found in standard texts such as West, 1972 and Faegri and Iversen, 1975).

For each level at least 500 pollen grains were identified and counted, unless there was a great predominance of tree pollen grains, in which case counting was stopped once a total of 150 tree pollen grains had been reached. The latter situation applied in general to the lower samples of the section HMC (below 130cm.)

The results of the pollen analysis of samples from the three sites are shown in Figs, 7-19. The pollen diagrams show the percentage of pollen grains of each type identified relative to the total number of tree pollen grains.

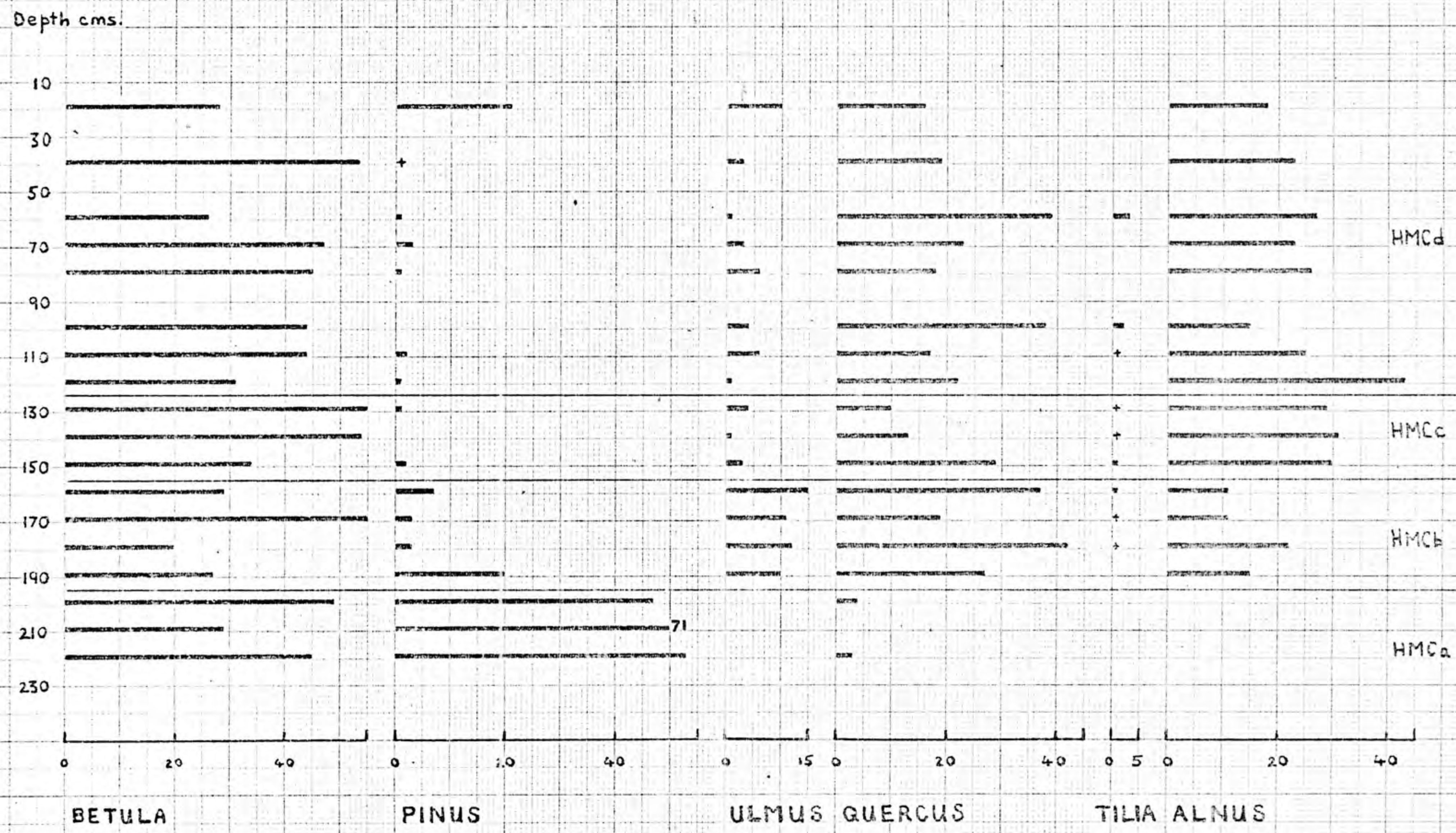


Fig. 7. Howden Moss Section C Tree Pollen (Figures as %age of T.T.P.)

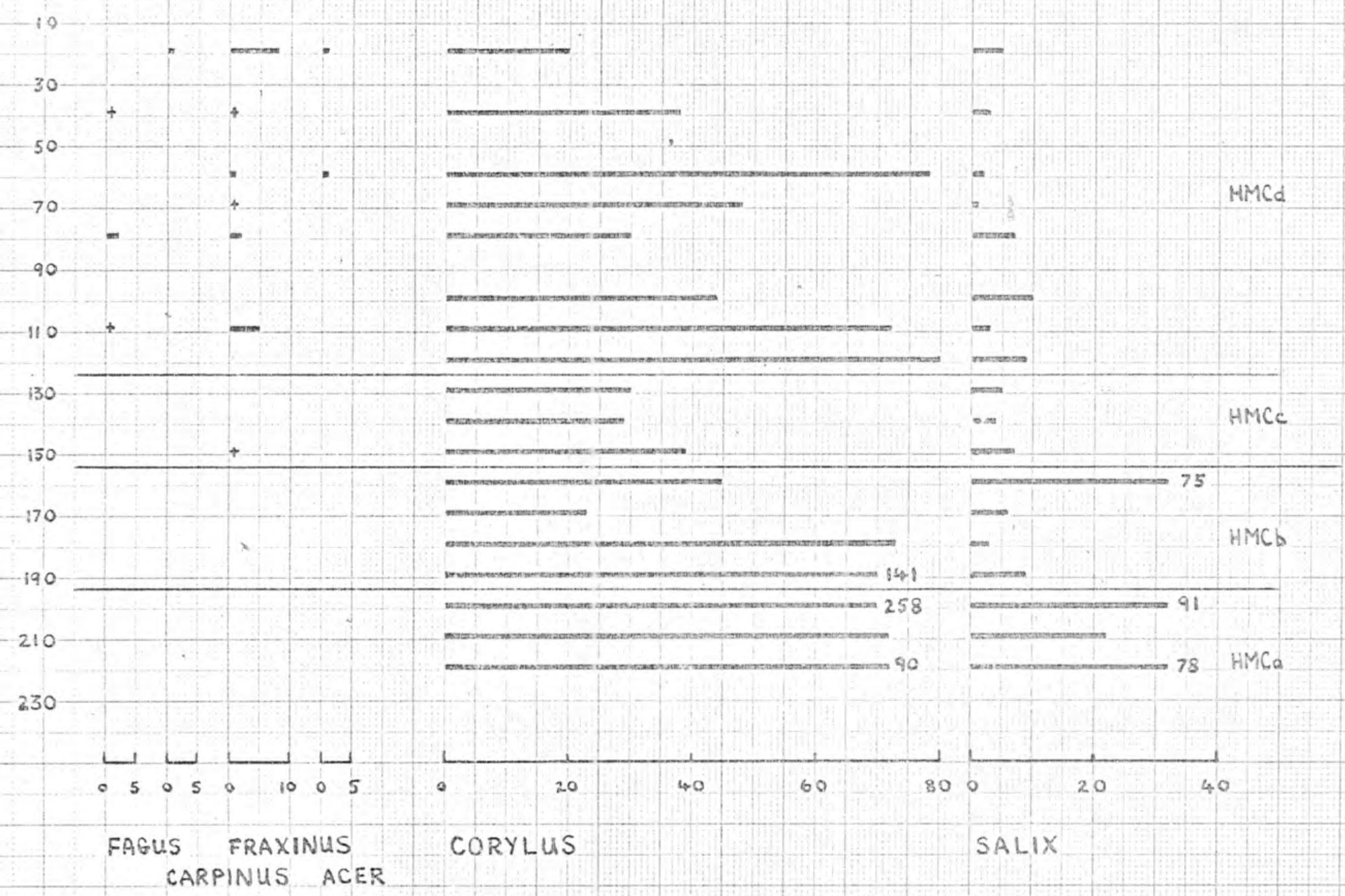
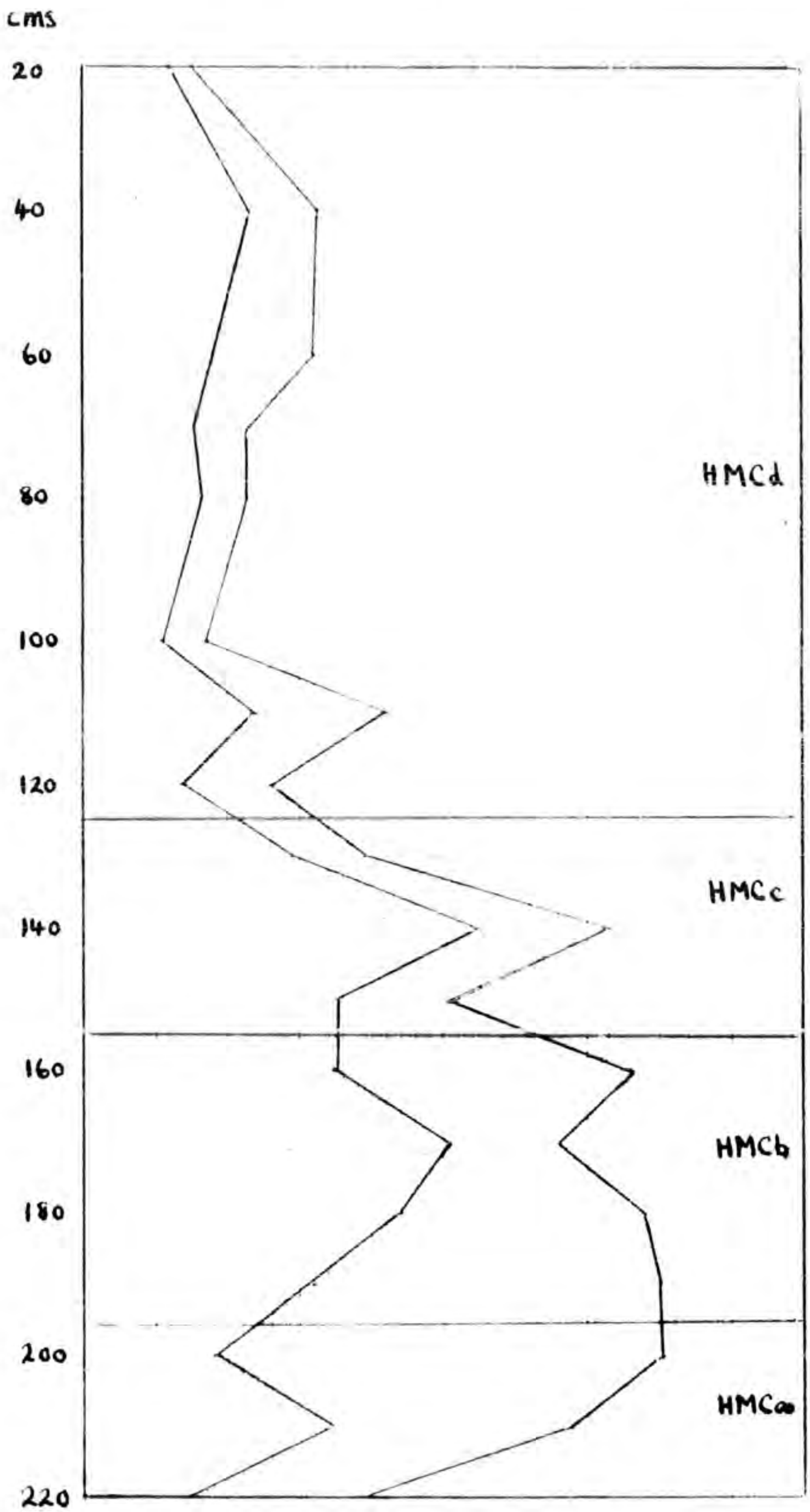


FIG. 8 Howden Moss Section C Tree and Shrub pollen (as % of TTP)

FIG 8A HOWDEN MOSS SECTION C



% age TREES/SHRUBS/HERBS

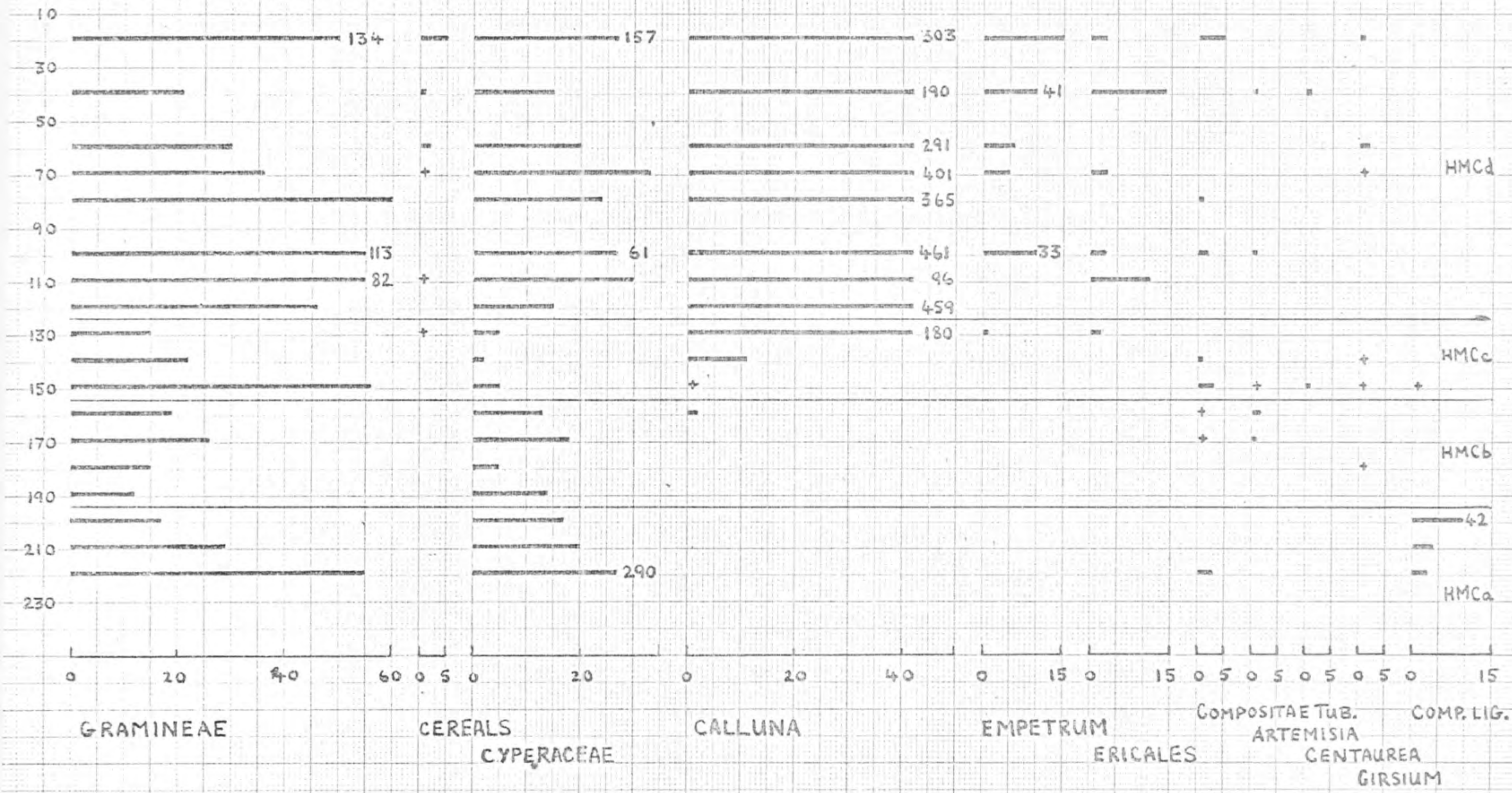


FIG. 9 Howden Moss Section C Herb Pollen (as % of T.T.P.)

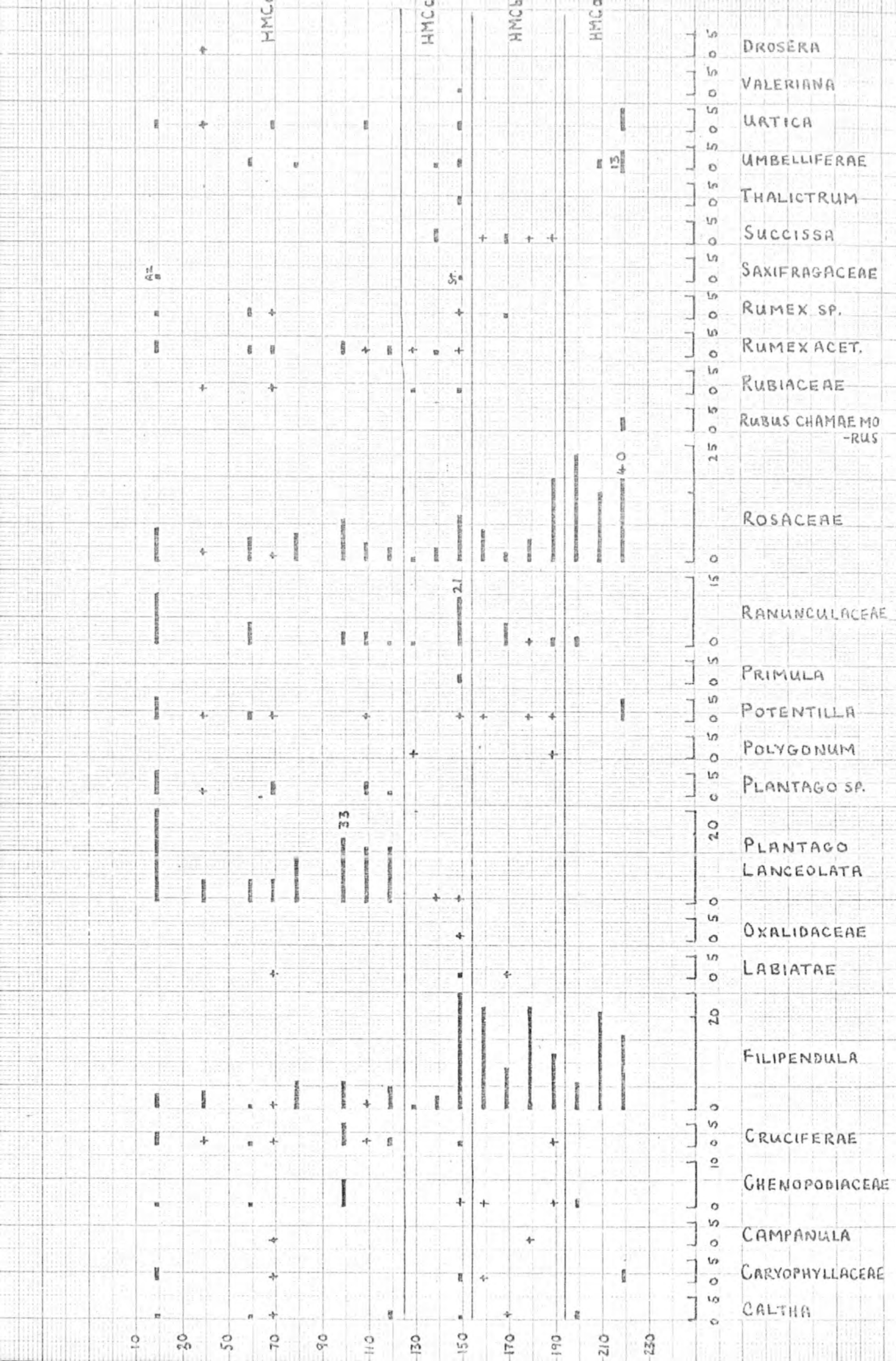
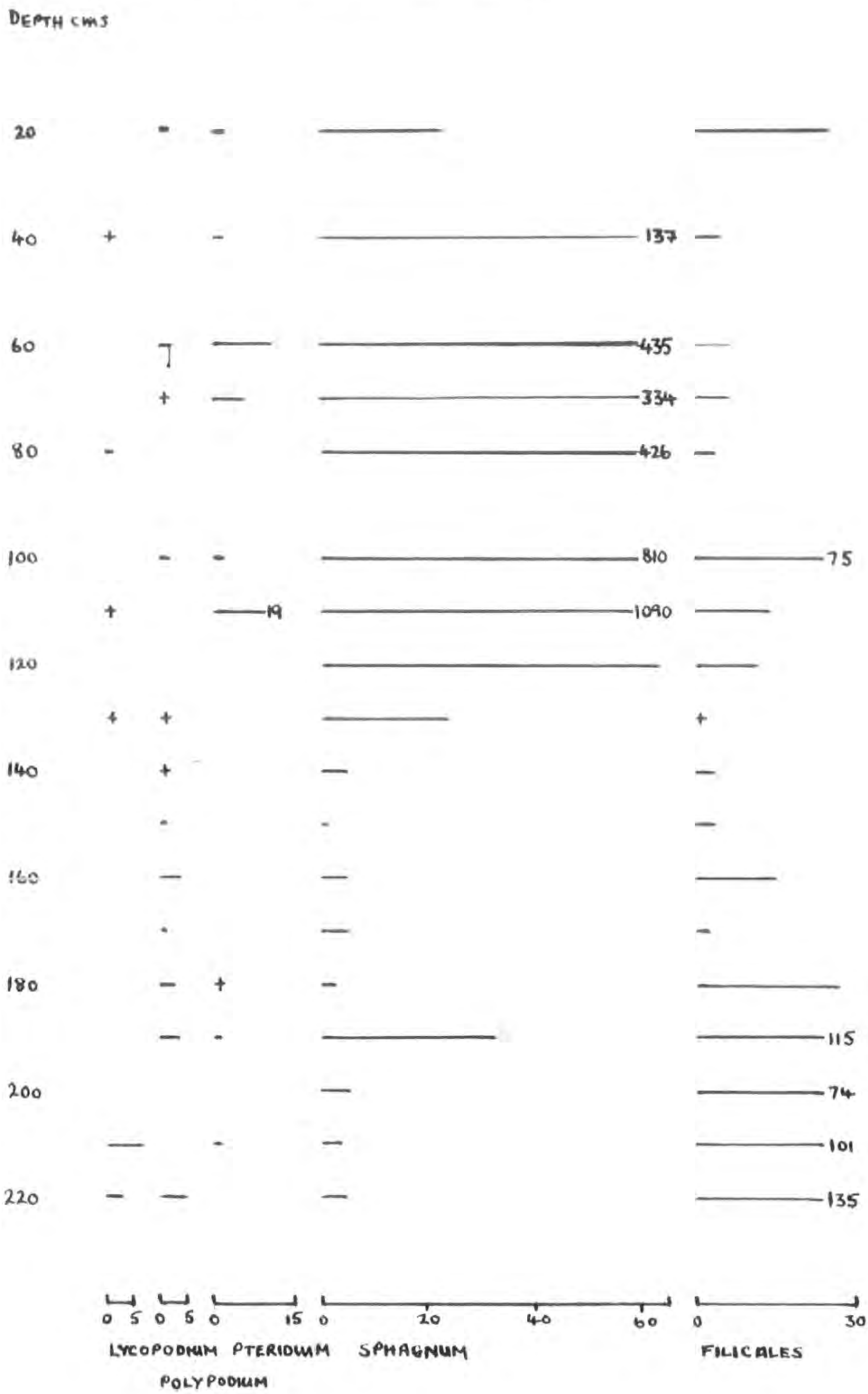


Fig.10 Howden Moss Section C Herb pollen cont'd.

FIG H HOWDEN MOSS SECTION C SPORES



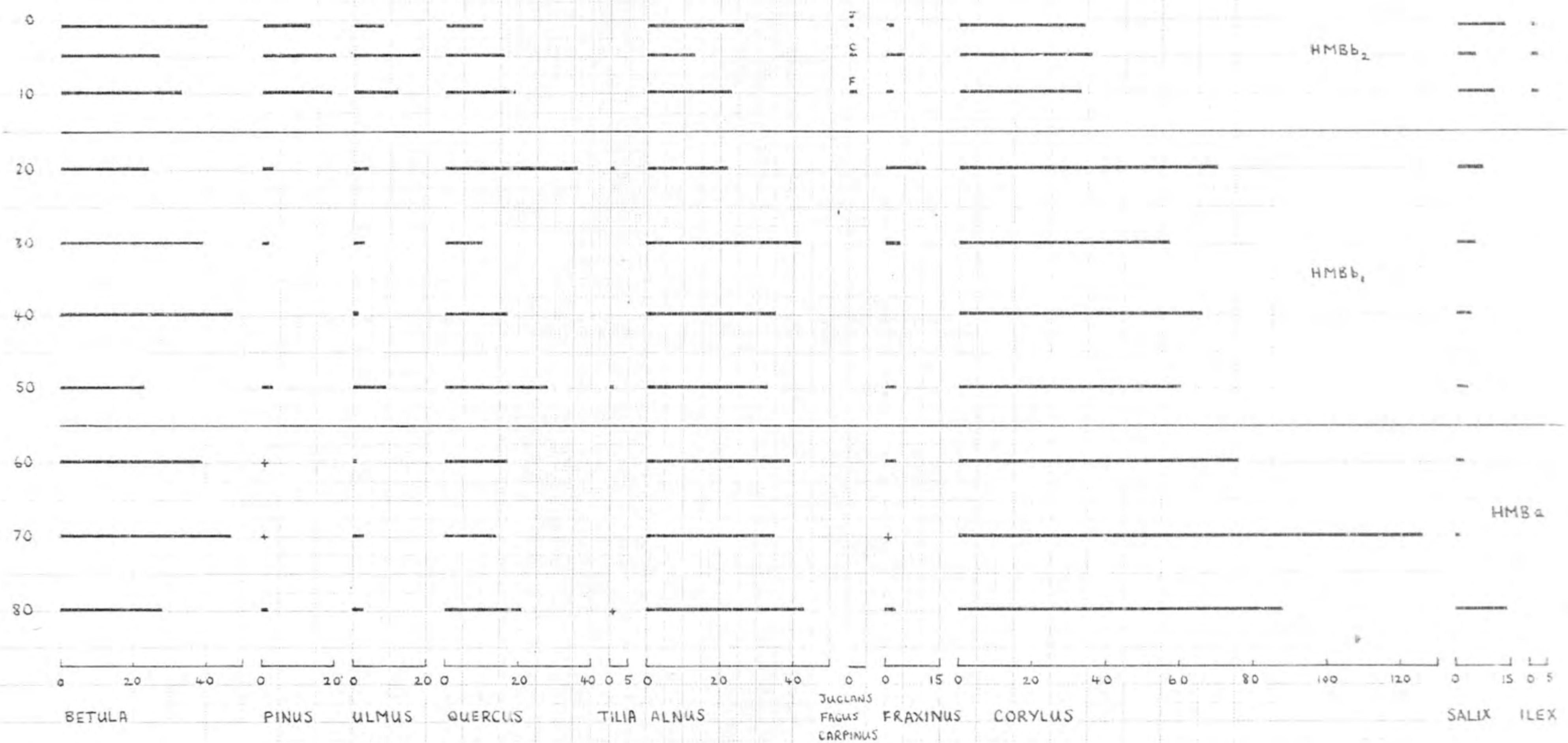


FIG.12 HOWDEN MOSS SECTION B TREE AND SHRUB POLLEN (EXPRESSED AS % OF T.T.P.)

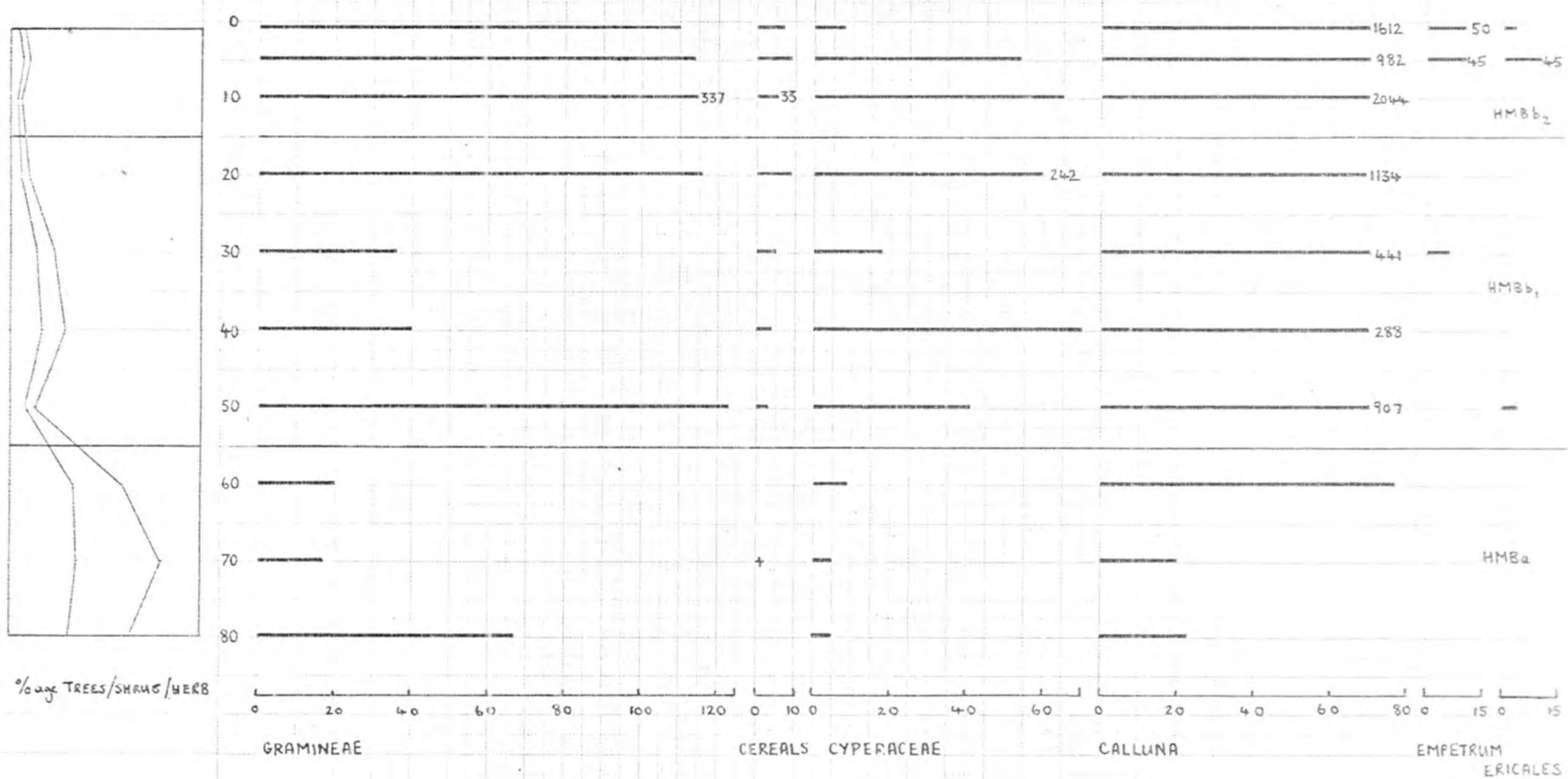


FIG.13 HOWDEN MOSS SECTION B HERB POLLEN (as % T.T.P.)

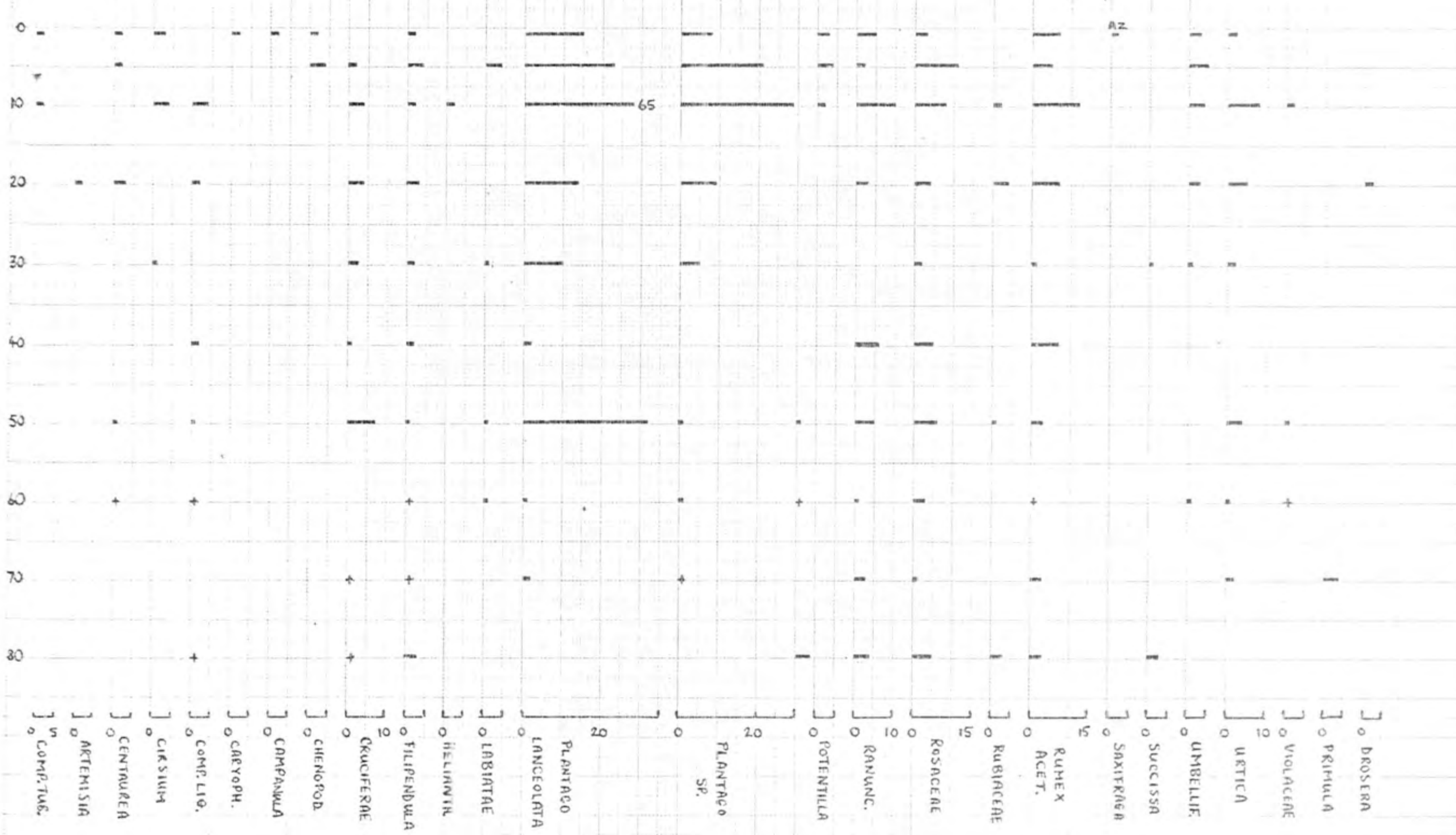
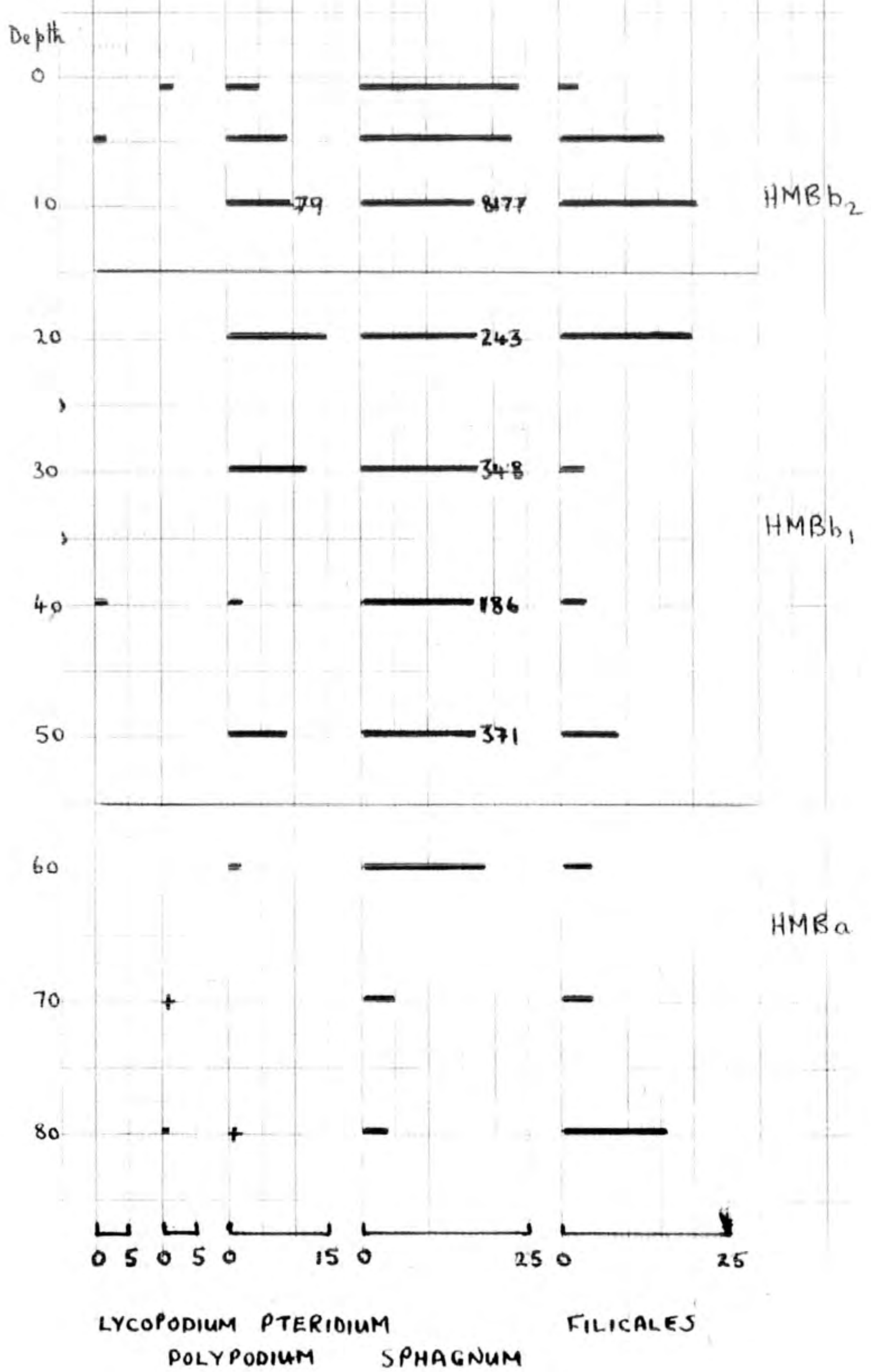


FIG.14 HOWDEN MOSS SECTION B HERB POLLEN CONT'D

FIG. 15 HOWDEN MOSS SECTION B SPORES



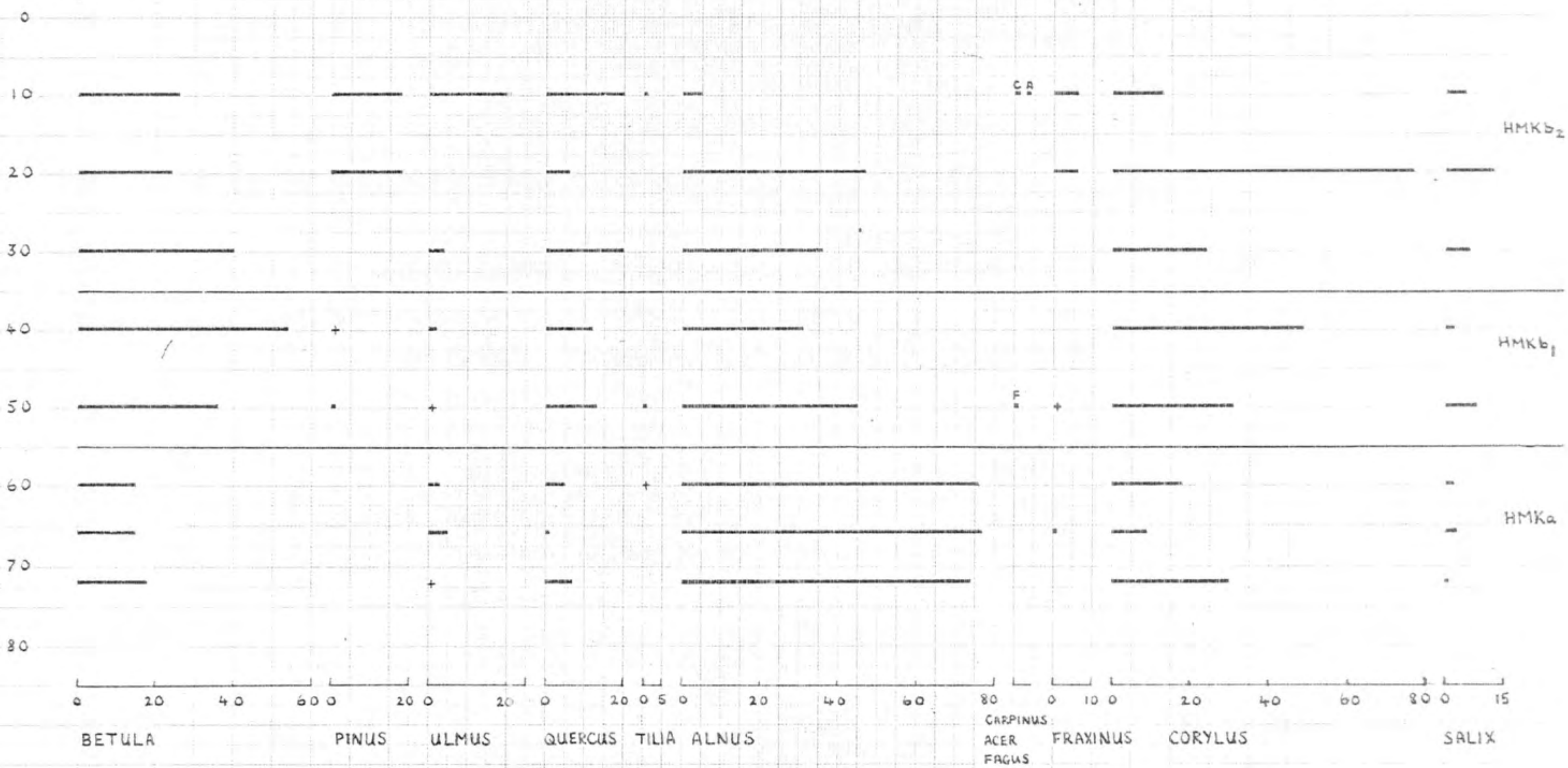


FIG. 16 HOWDEN MOSS SECTION K TREE AND SHRUB POLLEN (AS % of T.T.P.)

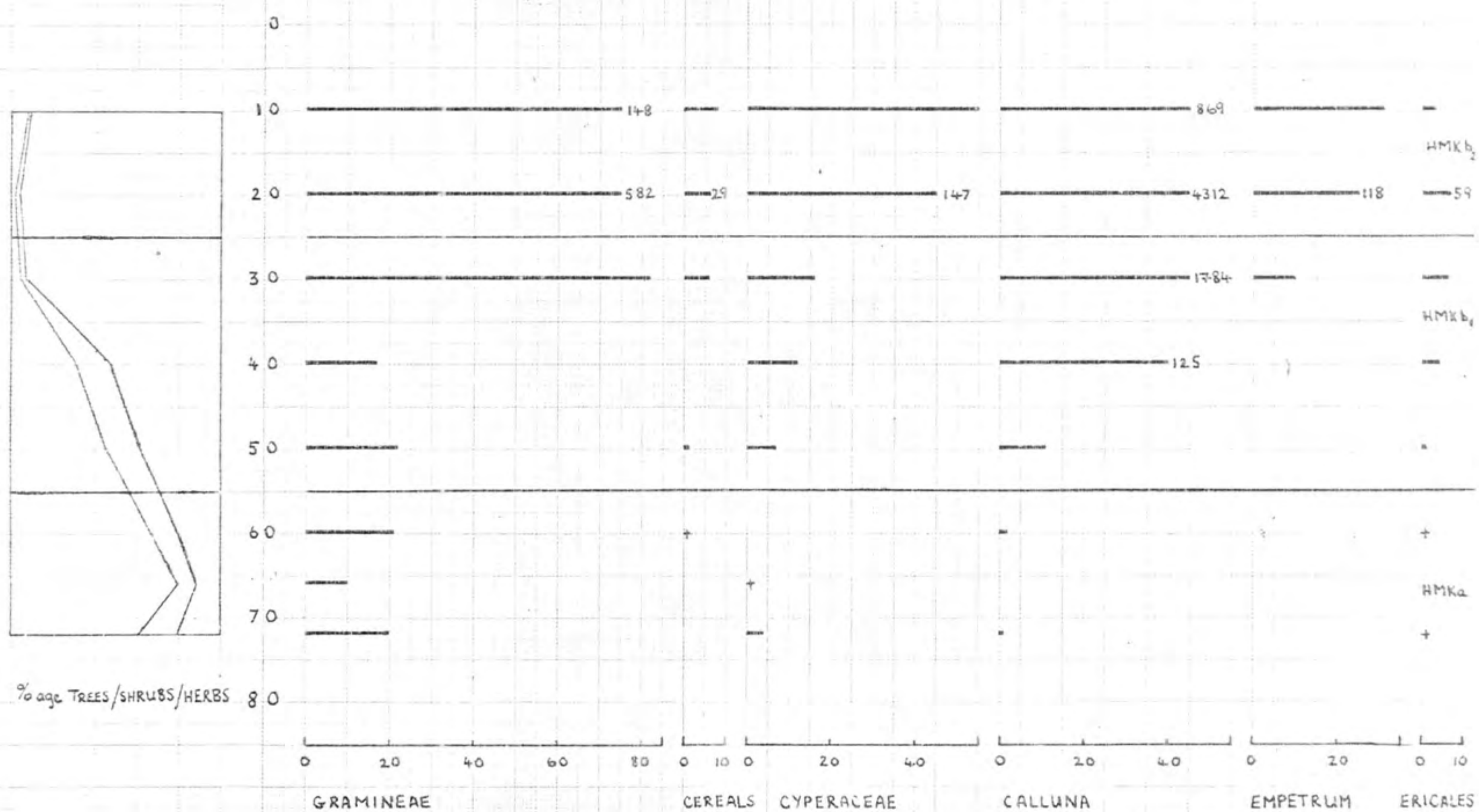


FIG.17. HOWDEN MOSS SECTION K HERB POLLEN (AS % T.T.P.)

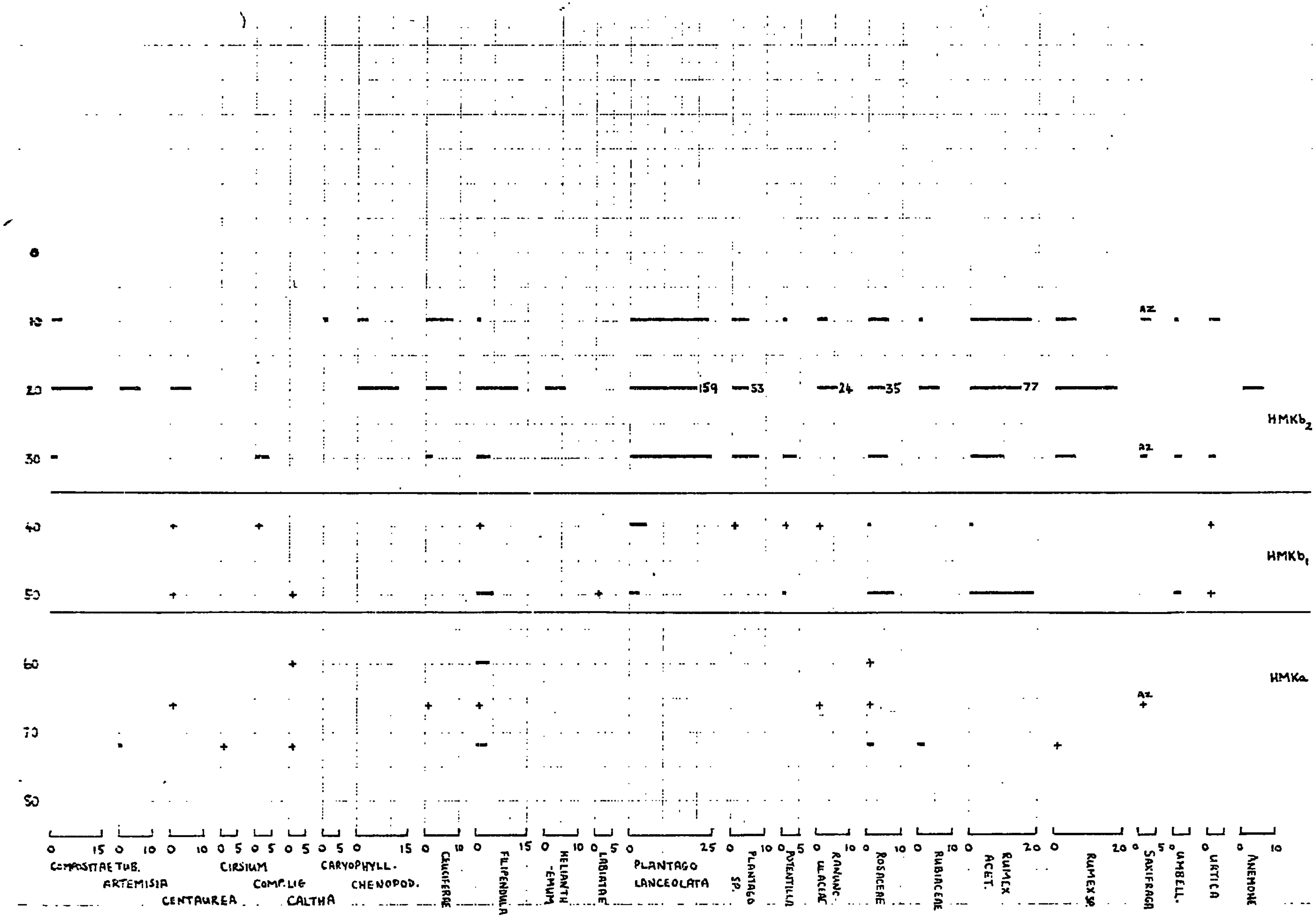


FIG. 18 HOWDEN MOSS SECTION K HERB POLLEN CONT'D

RESULTS OF POLLEN ANALYSIS

1) Zonation

The main pollen diagram HMC can be divided into four major pollen assemblage zones. The correlation between these and the assemblages recognized on the diagrams from sites HMB and HMK will be discussed later (see p.)

The assemblages recognized at HMC are as follows, beginning with the most recent:

heather-grass-plantain	zone HMCd
birch-alder	HMCc
birch-oak-elm	HMCb
hazel-pine-herb	HMCa

These local pollen assemblages can be related to the zonation scheme of Godwin (1956) and to West's Flandrain chronozone scheme (ibid, 1970). Godwin's scheme has been outlined in the Introduction (see fig. 1). That of West is essentially a tripartite scheme:

zone F III Anthropologically influenced
F II Forest maximum
F I Successional stages up to full forest development.

The pollen assemblages found at Howden Moss are not the same as those outlined by Godwin and West, but give a reasonable correlation when used in conjunction with Hewetson's radiocarbon dated diagram from Weelhead Moss in Upper Teesdale. (Hewetson, 1969; Turner et al, 1973).

Flandrian Chronozones	Godwin Zones	Weelhead Moss assemblages	Howden Moss assemblages
	VIII	grass-plantain-	heather-grass-
		-heather	-plantain
F III			
	-2550-		
		-3150-	
	VIIb	oak-alder	birch-alder
	5000-		
		-5220/5770-	
			birch-oak-
F II	VIIa	oak-elm-	
			-elm
	7050-	-hazel	
	VI	-8070/8057	hiatus
		hazel-pine	
	-8750	-------------	
F I			hazel-pine-
	V	hiatua	
			-herb
	-9450-		
	IV	-10020/10070-	
	10150-	juniper-willow-herb	

It appears that zone HMCa correlates with Godwin's zone V, zones HMCb and HMCc with VIIa and VIIb respectively; and zone HMCd with zone VIII. The correlation of zones HMCb and HMCc is based primarily on the elm decline as the pollen assemblages are dissimilar to those of Godwin. (The elm decline is generally used to define the VIIa/b transition in Britain eg. Smith, 1958, Conway, 1954).

2) Section HMC

The detailed stratigraphy of the section is given in figure 5. The basal layer of the peat, 230 -218 cm, directly overlies clay. Its pollen assemblage is basically herbaceous, dominated by Cyperaceae, but also with high levels of Corylus and Salix pollen. This would appear consistent with the early Boreal period, Godwin's zone v, with the low tree pollen count indicating an open environment.

The peat from 230 to 200 cms forms a pollen assemblage which has been called HMCa. The pollen spectra shows a predominance of pine, birch and hazel pollen. The quantity of shrub pollen varies throughout the zone. Herabceous pollen shows a rapid decline.

The zone from 190 - 160 cm. HMCb, has a birch-oak-elm assemblage. At the start of the zone, pine pollen declines to approximately half its previous value and oak pollen increases markedly. Associated with these changes is the sudden appearance of elm and alder pollen at 10% and 15% of total tree pollen, (T.T.P.) respectively.

The rapidity of the transition from one assemblage to the next is unexpected. It is possible that there is a hiatus in peat formation between the samples taken at 200 cm and 190 cm. This would mean that peat growth was not continuous at this site. This suggestion has previously been proposed to explain the sudden changes between pollen assemblage zones seen at other pollen sites in Upper Teasdale, (Turner et al, 1973) notably at Red Sike Moss and Weelhead Moss. Hiatuses at those sites occur at positions which are apparently earlier than at Howden Moss.

At Howden Moss there is no stratigraphic evidence to suggest a break in peat formation. However at 190 cm and 180 cm in the section there are large pieces of wood (birch) present, indicating that the bog may have been growing very slowly at this time. Very low growth would produce a similar result in the pollen record to a hiatus, especially in view of the fact that the 10 cm interval between samples could cover a large period of time.

From 150 to 130 cm there is another pollen assemblage, HMCc, consisting of birch, alder and oak. The begining of the zone is marked by a sudden drop in elm pollen and an increase in alder. Plantago lanceolata makes its first appearance in the form of single grains found at 150 cm and 140 cm. This plant is generally taken to be indicative of human activity.

The herbaceous pollen shows considerable changes in composition during the zone with Calluna becoming dominant at the expense of Gramineae. This is associated with the stratigraphic change from fen to 'blanket' peat. The low elm frequency found throughout the zone would appear to equate HMCc with Godwin's zone VIIb.

Above 130 cm the pollen assemblage is dominated by Calluna with Cyperaceae and Gramineae also prominant. Plantago lanceolata pollen becomes continuously present. The pollen spectra of this zone HMCd show tree and shrub pollen to be minor contributors. The corresponding zone under Godwin's scheme is zone VIII. Sphagnum spores consistently reach very high counts during this period, the general assemblage indicating a vegetation not dissimilar to that existing at present.

3) Section HMB

Two major pollen assemblage zones are evident at this site. The earlier zone, HMBa, consists of birch, alder and hazel. Tree pollen represents about one-third of the total pollen count. Elm pollen is at a low level and one or two grains of Plantago lanceolata are present. The Calluna content begins to rise at the end of the zone, as does the number of spores of Sphagnum.

From 50 cm upwards there is a second pollen assemblage. The pollen spectrum becomes dominated by Calluna and Sphagnum also assumes importance. Tree pollen falls to a low level and there is a large temporary increase in the pollen of Plantago lanceolata, from 1% to 32% of T.T.P. There are major increases in the pollen curves for Gramineae and Cyperaceae. Throughout this zone HMBb, cereal grains are evident. A minor division of the zone can be made at a point between 20 cm and 10 cm. Above this point pine and elm pollen rise noticeably although there is no great increase in tree pollen.

4) Section HMK

As at site HMB, two assemblage zones can be recognised on the pollen diagram from this section. The earlier zone HMKa is entirely dominated by alder pollen, which contributes over 75% of T.T.P. throughout. The elm pollen count is low in both this and the succeeding zone.

Silt is present in fairly large quantities in these lower levels (72-60). This is probably the result of slopewash considering the topography of the area round this site (see Fig.2), but it could conceivably have been deposited by wind erosion of exposed clay had the latter existed during the period the peat was forming.

The boundary between zone HMKa and the following zone HMKb is defined by a decline in alder pollen and the appearance of that of Planceolata and Rumex acetosella. Cyperaceae and Calluna pollen also begin to increase and Sphagnum appears.

The zone HMKb is characterised by a pollen assemblage consisting of Calluna, Gramineae and Plantago. A subdivision b_1/b_2 can be made above 40 cm., tree pollen reaching a very low level.

There is a slight suggestion of a hiatus in peat formation between 50 cm. and 60 cm. (the a/b boundary). A large increase in birch pollen occurs at this horizon together with a lesser increase in oak pollen. There is no obvious stratigraphic anomaly but the peat sample at 50 cm. is the only one from this site which does not contain silt. The significance of this fact is not however evident.

The major stratigraphic change in the deposit occurs at 45 cm. where there is a transition from a wood to a blanket peat.

5) Correlation of Pollen Assemblage Zones at Howden Moss

Correlation of the pollen diagrams from sites HMC and HMB appears to be relatively simple. The pollen assemblages of zones HMBa and HMBb are low in elm pollen and so apparently equate with the period following the HMCb/c boundary. This correlation is supported by the peat stratigraphy from the two sites (Fig. 5) and by the overall assemblages of the zones.

heather - grass - plantain = HMCd ≡ HMBb
birch - alder = HMCc ≡ HMBa

At first sight, it seems that the zones of the pollen diagram HMK form a similar sequence to those of HMB in that the peat at HMK apparently is post elm-decline. However, the analysis is not altogether satisfactory, both on the grounds of stratigraphy and pollen assemblages.

The major stratigraphic horizon at Howden Moss is the change from a wood or fen peat to 'blanket' peat. The transition occurs during zones HMCc, HMBa and HMKb. This would appear to be something of an anomaly as it suggests that blanket peat spread to the area of HMK much later than it did over the rest of Howden Moss. Stratigraphic examination of the peat near HMK does not support this suggestion (see Fig. 6).

The alternative explanation would be that there is a hiatus in peat formation at the site but again there is no stratigraphic evidence to support this theory.

There are extremely high levels of alder pollen during zone HMKa. These are not found at HMC or HMB and it is likely that a local alder stand was present near site HMK at this period. This suggestion has been used at Widdybank Fell (Turner et al, 1973) for an earlier zone. No alder remains have been identified in the peat and it is possible that alder was growing along the banks of Dry Beck as these would provide a more suitable habitat than the bog itself.

The levels of alder pollen found in zones HMCc and HMBa make it seem more likely that the zone HMKa correlates with these rather than with earlier zones. However, this can only be regarded as a rather tentative suggestion.

From the pollen assemblage of zone HMKb it is likely that this equates with zones HMCd and HMBb.

D I S C U S S I O N

1) Peat Development at Howden Moss

From the stratigraphic and pollen analytical evidence it seems probably that peat growth was initiated in the regions of the sites HMC and HMY early in the Boreal period. Patches of grassland were present, as evidenced by the monocoty ledonous 'turf' found at those sites. The pollen diagram from HMC suggests that some willows may have been growing on or near the grass. The high level of sedge pollen indicates wet conditions and it is possible that open water existed.

Woodland must gradually have spread over the area and the amount of water would be reduced. The basal wood peat contains abundant wood remains of which the majority, at least, are of birch. This peat varies in thickness over the area. The association of the wood with Phragmites remains suggests a fenwood period in which birch and reeds coexisted.

The common reed (Phragmites) can maintain itself in marshland (Tansley, 1968), although it is probable that it first needs open water to become established initially as reedswamp. This would support the previous arguments and implies that birch first colonised Howden Moss under wet marshy conditions.

Birch apparently became widespread over the 'bog', the surface of which presumably became drier as peat built up. This is evident in the reduction in Phragmites remains towards the top of the wood peat. Open woodland must have existed before the onset of conditions which led to the formation of the upper 'blanket peat'.

The change in peat type could represent one, or a combination, of three occurrences: a climatic change (probably to wetter); a successional change during bog development; human interference with the vegetation.

The initial plant communities would have grown with their roots in mineral rich soil. As these plants died and were replaced, deepening peat deposits were produced. The plant cover would eventually have become isolated from the mineral soil. Under conditions of low mineral supply a different type of vegetation would grow on the surface of the bog. (Pearsall, 1968).

The change in the macrofossil and pollen content of the peat is consistent with this type of development. Fen peat is base rich, dependent on ground water, and supports vegetation of the type Phragmites, Salix, Betula etc. The vegetation of the overlying peat includes Calluna, Eriophorum and Sphagnum, plants which can grow under acid conditions where the only mineral supply is through rainwater.

A climatic change could produce a similar alteration in vegetation. An increase in the precipitation: evaporation ratio would result in leaching of mineral salts and waterlogging of the ground. This in turn would produce an acid, mineral-deficient 'soil'. The regeneration of birchwood would be prevented and the vegetation would change with a consequent transition to a different type of peat.

The effect of human activity is essentially the same as that described for climatic change. By opening up the vegetation cover, precipitation is allowed to have an increased effect.

At Howden Moss the stratigraphic change in peat type does not always occur at similar heights above the substratum. This implies that developmental factors were not operative at least over the whole site. However, it is possible that once vegetation change was initiated on part of the bog the new communites gradually expanded and replaced the 'original' vegetation cover.

Climatic change could have caused the observed changes if conditions became wetter. There is some evidence to support this theory in that there is an increased alder pollen frequency preceding the stratigraphic change. However, it is impossible to determine the relative importance of the two factors as they produce similar results.

Anthropogenic agency could have acted as an initiator of change as there is evidence in the pollen diagrams from HMC of human influence near the bog at that time. It is possible that the different factors varied in importance at different parts of the bog.

2) Vegetational History

The vegetational development of Upper Teesdale, as recorded in the pollen diagrams from Howden Moss, will be discussed in conjunction with the results of previous studies carried out in this area, namely Hewetson (1969), Squires (1971) and Turner et al (1973). To avoid laborious repetition it may be assumed that, unless otherwise stated, general references to Upper Teesdale include evidence cited in those works.

The evidence from Howden Moss suggests that peat formation began at this site early in Boreal time. The covering of boulder clay would provide favourable conditions by impeding drainage (Johnson and Dunham, 1963). The pollen assemblage during the early part of this zone, HMCa, is consistent with an open herbaceous vegetation probably with a thin cover of birch and willow.

Pollen records show pine and hazel to be present in the area. The high values for these found at Howden Moss suggest that both became well established near the site. Hazel migrates rapidly into areas with little vegetation and would be one of the first colonisers in Upper Teesdale, probably existing as hazel scrub. (Erdtmann, 1931). Pine then spread into the area. The pollen values for pine vary in Teesdale and the actual location of the trees is problematical. The fact that Pinus in Britain is not now generally found on limestone soils suggests that only a few trees may have been growing in the valley. However, it is possible that patches of pine were present around the sandstone outcrops on Green Fell and Long Crag.

The general vegetation cover on the fellsides appears to have been open birchwood. At many sites abundant layers of birch are found in the peat. The pollen and macrofossil records from Howden Moss show that birch was growing on the site, but patches of hazel scrub may have been present on the adjacent drier areas.

At other sites in Upper Teesdale the pollen diagrams suggest that oak, elm and alder were beginning to spread into the valley during the Boreal period. However, at Howden Moss there is complete absence of pollen of both elm and alder. It seems likely that the pollen record is discontinuous at this site, the period during which these species began to invade Teesdale being apparently unrecorded. The fact that hiatuses are found at other sites at similar times (Turner et al, 1973) suggests that the climate may have been rather dry at this time, producing only very slow peat growth if any.

It seems that following this period the amount of pine began to decline. In the valley bottom this was presumably due to the expansion of mixed oak forest species. However, the pollen record from Howden Moss suggests that pine was replaced by hazel on the fells. The decline which occurs in tree pollen during this change is indicative of human activity. It has been suggested that Mesolithic man may have been present on the fells. The use of fire by this culture to clear vegetation and herd animals has been documented in a number of texts (eg. Zeuner, 1959), and this generally leads to the replacement of existing vegetation by the fire-resisant hazel which then forms hazel scrub (Rawitscher, 1945).

However, the decline in pine could have been climatically induced, occurring as it does around the time of the Boreal-Atlantic transition. Towards the end of the Boreal period the climate of the British Isles changed from continental to oceanic. This led to increased rainfall with some resultant leaching and podsolisation of soils (Pearsall, 1968). The latter occurrences are unfavourable for pine and would account for its decline, although they would be more likely to result in its replacement by the relatively acid-tolerant birch than by hazel.

During the Atlantic period (zone HMCb) birch pollen is consistently present together with oak, elm, alder and lime. It indicates that two types of vegetation were present. On the fellsides birchwood continued, as evidenced by the macrofossil remains. Meanwhile in the valley mixed oak wood was apparently expanding, as witnessed by the declining hazel values and low herb pollen throughout the zone. Hazel is a light-demanding species and is shaded out once the forest canopy begins to close, hence it is not found in closed woodland (Erdtmann, 1931).

During the Atlantic period alder spread onto many areas where the soil was becoming waterlogged. In those places where the soil was acid or mineral deficient it was absent and birch persisted. The wet climate appears to be in part responsible for initiation of blanket bog formation over large parts of the fells.

Towards the end of the Atlantic at Howden Moss there is a decline in tree pollen, due mainly to a decrease in birch. There is no evidence of any clearance of the valley oakwoods and it is possible that birch cover has been reduced on the fells due to replacement by blanket bog. At Howden Moss itself the peat stratigraphy shows birch to have persisted throughout the Atlantic and into the succeeding period, zone HMCc, except on the area around site HMK where it seems that there was a local stand of alderwood. The latter may have grown up from the valley along the banks of Dry Beck.

The end of the Atlantic is marked by a sharp decline in elm pollen and a great increase in that of herbaceous species. This elm decline is consistent throughout the British Isles and signifies the beginning of the Neolithic culture, (Pennington, 1974). At Howden Moss the HMCb/c transition is apparently synchronous with other vegetation changes consistent with anthropogenic interference.

The decline in elm pollen is associated here with a large increase in the pollen of grasses and the ruderals Planceolata, Rumex and Labiatae. It seems that human activity may have been occurring both in the valley and in the vicinity of Howden Moss. It is thought that the Neolithic peoples used elm as fodder for stalled animals and so affected the composition of oakwoods by reducing the number of elms (Tauber, 1965). Stone axes of the Neolithic period have been found on Holwick Fell to the east of Howden Moss (Raistrick, 1932) and it is possible that there was some clearance of trees around this area.

In Teesdale the elm decline is generally the point at which blanket bog begins to develop at the lower sites. In many places the change in peat type occurs before this horizon. However, at Howden Moss the change in stratigraphy, and consequently in the pollen assemblage, takes place some way above the elm decline.

Following the initial appearance of ruderals those species decline suggesting that human activity near Howden Moss had ceased and local tree cover increased. An increase in birch at the same time is probably largely due to expansion of those trees into cleared areas of oakwood to form secondary forest communities. There is also an increase in alder which suggests the ground in the valley may have been becoming wetter.

The widespread invasion of blanket peat seems to have resulted from a waterlogging of the peat. This is indicated by a large increase in Sphagnum as well as in Calluna. The vegetation change may have been effected by increased precipitation and encouraged by the removal of tree cover. A combination of leaching and climatic deterioration would prevent regeneration of trees.

By the beginning of zone HMCd most of the woodland on the fells had been replaced by blanket bog. The dominant vegetation throughout the period consisted of Calluna, Sphagnum and Eriophorum, although the contribution of each of these to peat formation varied with time at any one place. The different layers of peat produced probably reflect minor fluctuations in the climate and drainage regime of the bog areas.

The last important change in forest composition in the valley occurs at the HMCc/d boundary. Besides marking the point at which blanket peat was apparently reaching its major extent, there is a large increase in the pollen of grasses and plantains. Cereal grains also become more or less continuously present. The relative time of these occurrences suggests that they are the result of Iron Age settlement and agricultural activity.

A temporary woodland regeneration occurs following this period and Squires (1971) suggests that this may relate to the Romano-British period. At this time birch was probably recolonising abandoned fields.

Towards the end of peat deposition tree pollen declines still further. The main settlement period in Upper Teesdale was during the early 18th century and the present agricultural practices were probably established about this time (Piggott, 1956). The final stages in the clearance of almost all the woodland from the valley bottom took place shortly afterwards following the development of lead mining.

3) The Teesdale Rarities

The rare plants found at Upper Teesdale are postulated to be relics of a more widespread vegetation which existed in Late-Glacial times and which for some reason managed to survive both the subsequent climatic amelioration and the expansion of forest into Teesdale.

The unique assemblage is now only to be found growing in the eroding soils over the sugar limestone which has been formed in the area. Pollen analysis has shown that most of these plants were widespread over Britain following the retreat of the last glaciation. It seems that the plants owe their continued existence in Teesdale to the bedrock which readily crumbles and produces the unstable soil conditions which arctic and alpine plants are adapted to colonise. These conditions are not found in the area of Howden Moss.

None of these plants is now found in the vicinity of Howden Moss and the pollen record shows little evidence of their existence in the past. It seems that most of the arctic-alpine plants, such as Gentiana verna and Dryas octopetla were replaced at an early stage in the post-glacial period around this site, that is before peat formation began over most of Howden Moss, presumably because of colonisation of the area by hazel and pine.

The expansion of trees onto the fells would reduce the area these plants could inhabit as most are extremely intolerant of shade. It is possible that they may have continued to exist for some time near rock outcrops and calcareous flushes and springs which would have remained free from tree cover.

Pollen grains atributed to Polygonum (?vivparum) Primula farinosa, Saxifraga azoides, S. Stellaris, and Thalictrum have been recognised from the Section HMC and these are all found today as part of the Teesdale flora.

Apart from S. Azoids all the grains are associated with the lower wood peat and were presumably growing on grassland near the site, although not apparently continuously.

The 150 cm level at HMC is the point at which these are best represented and this appears to be related to human interference with the tree cover. The development of blanket bog seems to have destroyed the habitats which the plants were occupying. Only pollen of S. azoids is found after this point and it is possible that this plant continued to exist in a few areas until fairly recently.

From this study it would appear that the major difference between the areas bearing the relict flora and Howden Moss lies in the geologic structure. The climate and vegetational history of areas such as Widdybank Fell are essentially similar to that of Howden Moss except where outcrops of sugar limestone occur. It would appear that the characteristics of this rock are such that it produces an unstable soil in which the normal successional changes in vegetation which occurred elsewhere during the post-glacial period were prevented. Hence arctic-alpine plants were able to survive in small areas in Teesdale.

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